Acoustical Measurement of the Prandtl Number

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We have developed an acoustic resonator that is designed to measure the Prandtl number of gases. The resonator consists of a cylindrical chamber with an array of parallel plates placed midway between the ends. Once the effective area of the plates has been determined with a reference gas such as argon, the Prandtl number of the test gas is deduced from the frequency dependence of the longitudinal oscillations of the test gas. Acoustic energy loss in gases occurs primarily near solid surfaces, where the boundary conditions imposed by the surface on the motion of the gas create large velocity and temperature gradients within a very short distance from the surface. Shear, created by the no-slip boundary condition near a solid surface, leads to viscous damping of the gas motion. The isothermal nature of a solid surface, due to its large specific heat and thermal conductivity, leads to heat flow out of the acoustic wave. The large surface area of the plates increases the viscous damping of the odd-numbered longitudinal modes and also increases the thermal damping of the even-numbered longitudinal modes. From measurements of both even and odd modes, we obtain information about the viscous and thermal diffusivities of the test gas. Since the Prandtl number is the ratio of the viscous and thermal diffusivities, effects such as imperfections in the duct array cancel out to a large degree. The all-metal construction of this device makes it ideal for studying corrosive or hazardous gases over a wide range of temperatures. We present measurements made with this device of the Prandtl number of several gases including helium, xenon, helium-xenon mixtures, and sulfur hexafluoride.

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